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WRS-Canada: Integration of the Landsat Worldwide Referencing System with ecological, geographical, and demographic data

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Strategic Importance

Canadians are responsible for stewardship of approximately 10% of the world's forests. As a result, we as Canadians must be able to represent our forests in a manner which portrays a variety of economic, social, and environmental conditions. To meet these broad information challenges, the Canadian Forest Service of Natural Resources Canada, in partnership with the Canadian Space Agency, has begun to monitor Canada's forests with space-based technology and Landsat data through a long-term project, the Earth Observation for Sustainable Development of Forests (EOSD).

All Landsat satellite images of the earth's surface are collected on a Worldwide Referencing System (WRS). WRS partitions the globe into overlapping frames representing the locations where Landsat data has, and will be, collected. The WRS is a useful tool for image selection and cataloging, organization and processing, and the development of sampling techniques.

This technical transfer note outlines the information potential of WRS-Canada when integrating information such as forest cover, elevation, and population. The authors describe a new on-line tool that allows Web users to determine which WRS frames in Canada correspond to various political, ecological, topographical, and demographic characteristics. Examples of queries that this system can handle might include:

- Which Landsat frames contain areas that are over 500 metres in elevation?
- Which Landsat frames in British Columbia contain over 100,000 people?
- Which Landsat frames are more than 10% wetland?
- What proportion of forest cover can be expected by Landsat frame (figure 1)?

This type of information should facilitate land-use planning and decision-making for many stakeholders across the country.

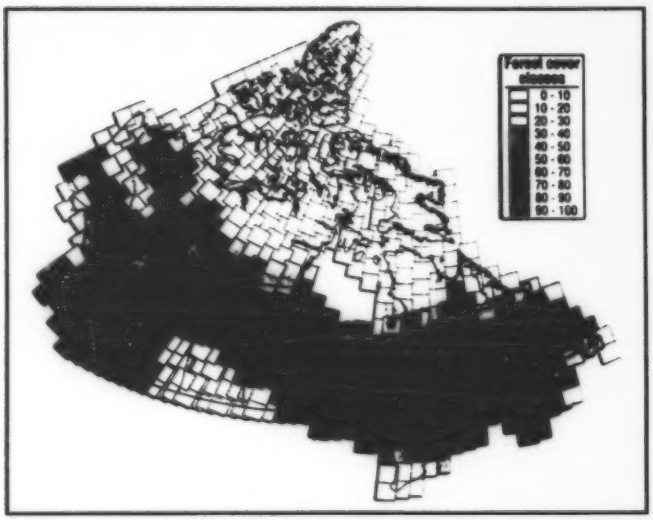

Figure 1. WRS over Canada with NBIOME aggregated forest cover.

Image Collection System – How it works

The WRS partitions the globe into frames indicating the extents of Landsat imagery. A "Path" and a "Row" number (determined by the scene's latitude and longitude) represent each frame. Paths run north – south in direction and are determined by the 16-day repeat cycle of Landsat sensors (approximately 233 orbits). The Rows are generated by partitioning each Path into 23.92 seconds of spacecraft time in both directions at the equator resulting in 248 Rows per complete orbit.

The Landsat sensors continuously collect data. Telemetry ephemeris data segments data into individual framed scenes on the ground. Framing is unique for each orbit, although the frame locations are not exact. Frames are within a tolerance of movement from the original satellite orbit. The satellite orbit results in a coverage side overlap of a minimum of 7.3% at the equator increasing to approximately 85% at 80° latitude.

Selected national data sets can be extracted using the Landsat WRS as the sampling frame. The Landsat WRS can be merged with national spatial data sets such as the Northern Biosphere Observation and Modeling Experiment (NBIOME) land cover map, GTOPO30 elevation data, and Statistics Canada census data. Once the national data sets have been described and the information extraction exercise outlined, select results can be presented spatially (by location) and aspatially (in tabular format).

The overlapping coverage between each of the frames can be portrayed by creating a GIS coverage of regions, where each region is a Landsat frame. For example, the overlap of images in southern Canada is approximately 40% increasing to over 80% in northern Canada. Consequently, there is a need to reduce or thin the net to allow us to determine minimum numbers of frames required for areal coverage, particularly in northern Canada. The result will aid in image selection and planning for provincial and national level remote sensing projects.

The un-thinned net (over 1200 image frames) is used as the basis for an image cataloguing system. Thinning reduces the number of scenes to 712 while maintaining complete coverage and minimal redundant imagery. The un-thinned coverage is available as an ArcInfo .e00 export file at: www.pfc.cfs.nrcan.gc.ca/eosd/cover/wrs_e.html

Attributes such as the path, row, area, geographic location, province(s), ecozone(s) and frame identifier are stored for all frames. Provincial and federal boundary information provided from the Natural Resources Canada initiative "GeoGratis" creates two attributes: one allows for multiple provinces per scene, and the other give scenes the provincial label with the greatest area in the frame.

Canadian terrestrial ecozones are subject to the same methods and rationale as provinces. The spatial extents and centers of each frame are also included to aid in geographic querying. Appendix 1 provides a key for accessing WRS-Canada forest attributes.

Frame Attribute Sample

Name	Value
TM_PATH	51
TM_ROW	22
PROV_BC	1
PROV_AB	0
PROV_SK	0
.	.
.	.
.	.
ELEV_MIN	282
ELEV_MAX	2694
ELEV_MEAN	1020
ELEV_STD	273
ELEV_RANGE	2412
NEWPOP	24547

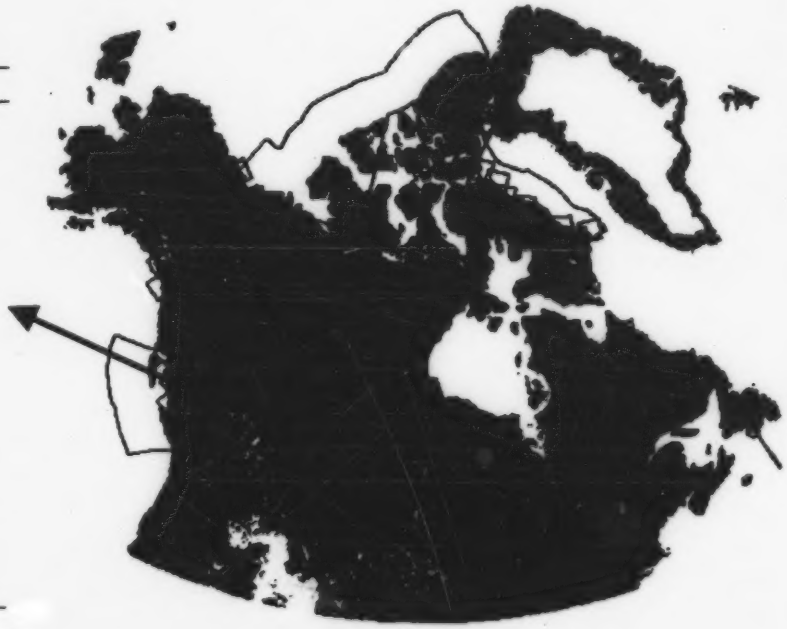

Figure 2. Example of the fusion of WRS-Canada with GTOPO30 elevation data. GTOPO30 elevation data provides the image backdrop, the WRS frames (in black) illustrate all locations where the mean elevation is greater than 500 meters. The table indicates a subset of the information available from the online database.

Applications

1. NBIOME Land cover

A national land cover map from Advanced Very High Resolution Radiometer (AVHRR) satellite data has been produced through collaboration between the Natural Resources Canada sectors and the Canada Centre for Remote Sensing (Cihlar and Beaubien 1998). The AVHRR imagery is approximately 1.1 km spatial resolution at nadir and greater off nadir, resulting in a mosaic with an effective spatial resolution of approximately 4 km.

The land cover map, a component of NBIOME, is derived from imagery collected from April to October of 1995. The NBIOME map is composed of 1 by 1 km pixels.

The land cover of Canada is placed into 31 land cover classes. Each WRS frame is populated with a summary of the NBIOME map to enable selection of Landsat imagery. The area of each land cover type found within a given frame is recorded as a percentage of the total land area within the frame.

2. GTOPO30 Digital Elevation Model (DEM)

The authors chose to use the public domain GTOPO30 DEM, available from a consortium of organizations led by the United States Geological Survey (Gesch et. al. 1999), to categorize imagery based upon the internal elevations within each WRS frame. Elevations in the GTOPO30 model are spaced 30 arc seconds apart, which coincides with an approximately 1 km spacing. The elevations from the GTOPO30 DEM result in more than 60 000 data points per Landsat frame to be summarized.

Images with a large range in elevation may be selected for analyst intervention to investigate topographic and subsequent radiometric issues. Data may also be used to select imagery for studies of attributes that have elevation constraints.

3. Census Data

Another example of the application of WRS-Canada's stratification system is the ability to aggregate population by census subdivisions and show changes over time. For the 1996 Statistics Canada census, there were 5984 census subdivisions within Canada. Some fragmented census subdivisions are located within larger subdivisions, resulting in a polygon coverage composed of 8358 polygons. For each census subdivision, we have population totals and area statistics. We have summarized each frame with total population, to aid in the selection of Landsat imagery.

The National Forest Information System (NFIS)

The Canadian Council of Forest Ministers (CCFM) agreed in 2000 to develop the National Forest Information System (NFIS), an information infrastructure to demonstrate sustainable forest management practices within Canada. NFIS will:

- provide ready access to current, consistent and reliable forest resources information;
- provide the transparent integration of information across jurisdictional boundaries;
- provide consistency in reporting; and,
- reduce costs through the sharing of information technology.

NFIS uses software architecture composed of a database layer (Oracle 8i®), a spatial handling layer (CubeStor®), a map server layer (CubeServ®), and the web navigation application (CubeView®). CubeStor enables the storage of spatially referenced objects within a relational database. Vast, seamless, multi-dimensional data can now be stored and retrieved easily. GIS data such as raster images, vectors, matrices, and points are stored and indexed efficiently.

CubeServ is a fully Open GIS Consortium (OGC)-compliant, cascading, Web-mapping server that allows for other servers to portray images and data over the Web. Many companies have adopted the OGC standards and have built their own servers. Web maps can be created from any number of servers that have varying map projections and varying data formats (e.g., Shape, IGDS, etc.). With this technology, a user will be able to compose a map containing data from different jurisdictions (e.g., provincial or municipal) and from different GIS architectures. The adoption of public international standards will allow the NFIS infrastructure to expand easily. Services and data will be available and reusable with fewer limitations. Access control and authentication modules will be used to ensure proper security measures are taken.

Database Query of WRS-Canada with NFIS

To view the WRS-Canada database, go to www.pfc.cfs.nrcan.gc.ca/eosd/cover/wrs_e.html using your web browser. A view of the NFIS-PFC portal is presented in Figure 2. Information on the data store may be viewed by selecting the "Details" button. Additional information on the attributes available is presented in Appendix 1. A variety of user options are available, including: setting the extents of the viewed area, panning of the viewable area, selection of themes and layers, and a query tool. A nested data storage

structure is used to view multiple layers and to query individual layers. For instance, the Data Stores (mid-page) identifies the source of the information. Themes are groups of available data. Selected Layers are the actual information that may be viewed. Questions about Canada's forests may be asked on-line of WRS using a CubeWerx query format.

The Landsat WRS for the entire globe may be obtained by contacting the United States Geologic Survey – Earth Resources Observation System (USGS - EROS) Data Center. The WRS of Canada has been clipped from this global information source and has been loaded into the National Forest Information System (NFIS) web site.

Selected layers may be included for viewing by using the "Add →" button. In the Selected Layers box, the layers are ordered for viewing and the layers are drawn as listed, i.e. Provincial Boundaries under Landsat WRS layers. The "Up" and "Down" buttons may be used to alter the order of layers. The order of the layers is also important when building "where clauses" (to query the database). The where clause (bottom of Figure 3) searches for the identified criteria in the first (or top listed) layer as the default. With the Landsat WRS layer positioned first in the Selected Layers box "where clauses" may be written directly, such as:

PER_FOR > 10

- Query for forest percentage greater than 10% of frame;

Or

PER_FOR > 50 and NEWPOP > 100000

- Query for forest percentage greater than 50% of frame and an expected population in the frame of greater than 100000.

If the Landsat WRS layer is not listed first in the Selected Layer box, a comma may be placed before the where clause to advance through the list of layers. For example if the Selected Layer box was filled first with Provincial Boundaries then Landsat WRS, then the query for all frames with greater than 10% forest cover from above would look like:

, PER_FOR > 10

More commas may be added to accommodate additional layers. As identified above, with the search for forest cover and population criteria, Boolean operations are permitted. For example, following SQL rules, a variety of queries may be formed,

PER_FOR > 10 and

(PROV_AB = 1 or PROV_SK = 1 or PROV_MB = 1)

- Query for Prairie province images with greater than 10% forest cover expected

Conclusion

In sum, the fusion of the Landsat WRS with spatial data has provided a valuable method for the selection of Landsat imagery to represent aspects of Canada's environmental, topographic, and social characteristics. The WRS-Canada database can depict changes in Canada's land spatially and aspatially, aspatial tabular data provides raw information from which image selection decisions may be based, and the spatial presentation of the results allows for the locational context of the query results to be considered. Additional attributes may in future be added to WRS-Canada. This capability enables a graphical means for organizing and cataloguing of large numbers of Landsat scenes. The database may be queried using the National Forest Information System (NFIS) or data may be downloaded by users to develop customized uses and applications.

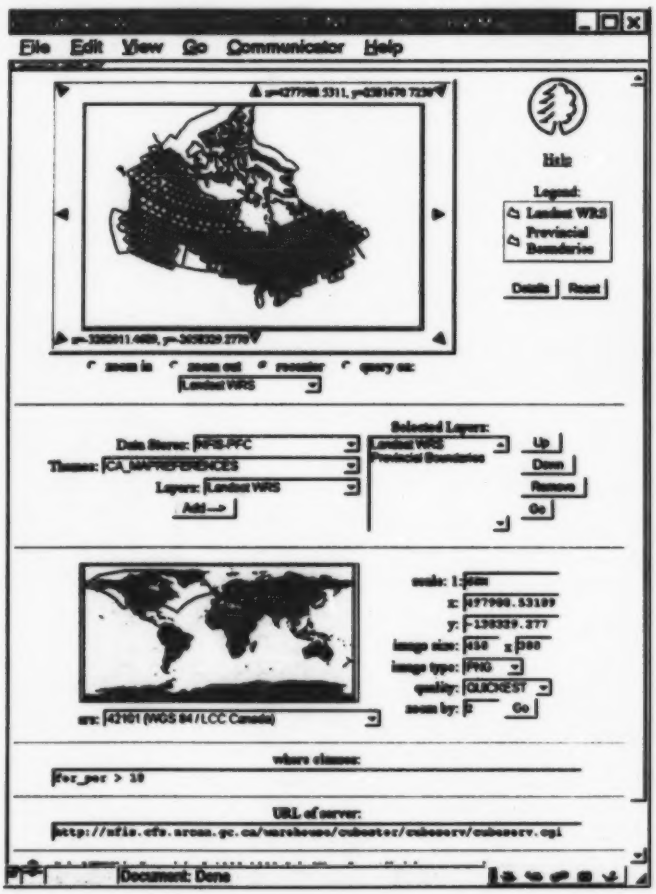

Figure 3. Screen capture of NFIS rendition of WRS-Canada. Sample query: forest percentage > 10%

Appendix 1. Description of WRS-Canada fields and related characteristics.

Name	Description	
TM_PATH	Landsat Path	
TM_ROW	Landsat Row	
TRFR_ID	A unique number combining Path and Row	
INCANADA	If this item contains a 1, then the frame in question overlays the Canadian land mass	
PROV_BC PROV_AB PROV_SK PROV_QC PROV_NS PROV_NB PROV_PE PROV_YT PROV_NT PROV_NF PROV_ON PROV_NU PROV_MB	If one of these items contains a 1 (versus a 0) then the frame overlays a portion of the province or territory indicated. When frames overlay a provincial/territorial boundary then multiple items are selected.	
ECOZ_AC	Ecozone: Arctic Cordillera	When one of these items contains a 1 (versus a 0) then the frame overlays the ecozone indicated. As above, there could be multiple occurrences.
ECOZ_NA	Ecozone: Northern Arctic	
ECOZ_SA	Ecozone: Southern Arctic	
ECOZ_TP	Ecozone: Taiga Plains	
ECOZ_TS	Ecozone: Taiga Shield	
ECOZ_BS	Ecozone: Boreal Shield	
ECOZ_AM	Ecozone: Atlantic Maritime	
ECOZ_MP	Ecozone: Mixed Wood Plain	
ECOZ_BP	Ecozone: Boreal Plain	
ECOZ_P	Ecozone: Prairies	
ECOZ_TC	Ecozone: Taiga Cordillera	
ECOZ_PM	Ecozone: Pacific Maritime	
ECOZ_MC	Ecozone: Montaine Cordillera	
ECOZ_HP	Ecozone: Hudson Plain	
ECOZ_BC	Ecozone: Boreal Cordillera	
PR_FOREST	NBIOME: expected percentage of forest in a frame	
PR_BURN	NBIOME: expected percentage of burned land in a frame	
PR_WET	NBIOME: expected percentage of wetland in a frame	
PR_OPEN	NBIOME: expected percentage of open areas in a frame	
PR_GRASS	NBIOME: expected percentage of grassland in a frame	
PR_BARREN	NBIOME: expected percentage of barren land in a frame	
PR_CROP	NBIOME: expected percentage of crop land in a frame	
PR_URBAN	NBIOME: expected percentage of urban land in a frame	
PR_WATER	NBIOME: expected percentage of fresh water in a frame	
PR_OCEAN	NBIOME: expected percentage of ocean in a frame	
PR_ICE-SNOW	NBIOME: expected percentage of ice or snow in a frame	
ULLONG / ULLAT URLONG / URLAT LRLONG / LRLAT LLLONG / LLLAT	Upper Left, Upper Right, Lower Right, and Lower Left geographic boundaries of each frame.	
ELEV_MIN	GTOPO 30: minimum elevation within a frame	
ELEV_MAX	GTOPO 30: maximum elevation within a frame	
ELEV_MEAN	GTOPO 30: mean elevation of the fame	
ELEV_STD	GTOPO 30: standard deviation of elevation values within the frame	
FRAMEPOP	Canadian census data: expected population within a frame (number of people per frame)	
FRAMEPOPDENHA	Canadian census data: expected population density within a frame (population per hectare)	
ROADLENGTH	Canadian Road Network: expected length of roads (km) within a frame	
REGION1 REGION2 REGION3	Ecoregion: Numeric codes for the three most prevalent ecoregions within a frame	

References

Cihlar, J.; Beaubien, J. 1998. Land cover of Canada Version 1.1. Special Publication, NBIOME Project. Produced by the Canada Centre for Remote Sensing and the Canadian Forest Service, Natural Resources Canada. Available on CD-ROM from the Canada Centre for Remote Sensing, Ottawa, Ontario.

Gesch, D.; Verdin, K.; Greenlee, S. 1999. New land surface digital elevation model covers the earth. Eos Transactions, American Geophysical Union, 80(6): 69-70.

Wulder, M.; Seemann, D. 2001. Spatially partitioning Canada with the Landsat Worldwide Referencing System. Canadian Journal of Remote Sensing 27(3):225-231.

Additional Information

WRS site:

www.pfc.cfs.nrcan.gc.ca/eosd/cover/wrs_e.html

USGS information on WRS system:

edcwww.cr.usgs.gov/glis/hyper/guide/wrs.html

USGS information on GTOPO30 elevation data:

edcdaac.usgs.gov/gtopo30/gtopo30.html

Government of Canada free map data:

geogratis.cgdi.gc.ca/frames.html

Centre for Topographic Information:

www.cits.RNCan.gc.ca/

The CFS Bookstore:

bookstore.cfs.nrcan.gc.ca

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For additional information on the Canadian Forest Service and these studies visit our website at:

www.pfc.cfs.nrcan.gc.ca

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